Massoud Kaviany

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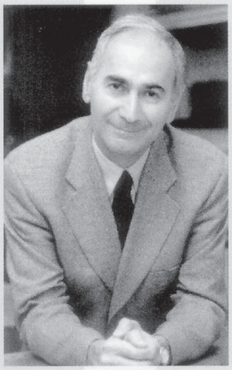

Massoud Kaviany is a Professor in the Department of Mechanical Engineering, and is also with the Applied Physics Program, at the University of Michigan, where he has been since 1986. His Ph.D. is from the University of California-Berkeley in 1979. His area of teaching and research is heat transfer, with a particular interest in porous media.

As his educational contributions, he has written two monographs, *Principles of Heat Transfer in Porous Media* and *Principles of Convective Heat Transfer*, and an undergraduate textbook, *Principles of Heat Transfer*. He has been the recipient of the College of Engineering Education Excellence Award (2003) at the University of Michigan, and departmental teaching awards. He was the Midwest Region Vice-President (2001-2004) of the National Council of Pi Tau Sigma (Mechanical Engineering Students Honor Society), and had served as the faculty advisor of the University of Michigan chapter (1992–2004). Currently he is working on the course notes for a new graduate course, Heat Transfer Physics. The course offers a unified treatment of phonon, electron, fluid particle, and photon transport and interaction. It combines the fundamentals of statistical thermodynamics, transport theories (including Boltzmann and stochastic transport), molecular dynamics (including lattice dynamics, with computer codes), solid-state physics (including semiconductors), and radiation transport, as related to heat transfer and thermal energy conversion.

His research has been on macro and micro-scale transport and interaction in porous media. Current projects include molecular dynamics simulation of phonon transport in porous crystals (phonon localization), laser cooling of ion-doped nano powders (phonon band broadening and enhanced photon absorption), and nano heat pipes (dominated by adsorption/desorption and surface diffusion). He is an editor for the *Journal of Microscale Thermophysical Engineering*, had been (1996-1999) an Associate Editor for the *ASME Journal of Heat Transfer*, and is on the editorial board of the *International Journal of Heat and Mass Transfer* and a few other international journals. He is an ASME Fellow since 1992, and the recipient of the 2002 ASME Heat Transfer Memorial Award (Science), for "investigating heat transfer in porous media and compiling an extensive body of research results in the internationally recognized and widely-used book." He was the Chair (1995-1998) and is a member (1982-present) of Committee on Theory and Fundamental Research (K-8), Heat Transfer Division, ASME. His research has been sponsored by several industries and by DOE, EPA, NASA, and NSF.

Laser Cooling of Solids

With the recent increase in science content of graduate engineering education, engineering academic disciplines (such as heat transfer) evolve to add such contents to the student classroom and research experiences. Heat transfer physics describes atomistic mechanisms of thermal energy storage, transport, and conversion. Heat is stored in thermal motion of electron, nucleus, and molecule, in various phases of matter. These energy states and their population are described by the classical and quantum statistical mechanics and the combinatoric probabilities. Transport of thermal energy is by electron, fluid particle, and photon, with their particle/wave descriptions, their thermal/diffusion/propagation/flow velocities, and the scattering losses they encounter as they travel. The mechanisms of energy transformation amongst these energy carriers, and their rates, are governed by the match of their energies, their probabilities, and the various hindering-mechanism rate limits. Conservation of energy describes the interplay amongst energy storage, transport, and conversion, from atomic to continuum scales.

As an example consider enhanced laser cooling of ion doped nanocrystalline powders (e.g., Yb^{3+}: Y_2O_3). This can be achieved by enhancing the anti-Stokes off-resonance absorption, which is proportional to the three design-controlled factors, namely, dopant concentration, pumping field energy, and anti-Stokes transition rate. The optimum dopant concentration for cooling shows that higher dopant concentration increases absorption, while decreasing quantum efficiency. Using the energy transfer theory for concentration quenching, the optimum concentration corresponding to the maximum cooling power is found. The pumping field energy is enhanced in random nanopowders compared with bulk crystals under the same irradiation, due to the multiple scattering of photons. Photons are thus localized in the medium and do not propagate, increasing the photon absorption of the pumping beam. Using molecular dynamics simulations, the phonon density of states (DOS) of the nanopowder is calculated, and found to have broadened modes, and extended, small tails at low and high frequencies. The second-order electronic transition rate for the anti-Stokes luminescence is calculated using the Fermi golden rule, which includes the influence of this phonon DOS, and is shown to have enhancement effects on the laser cooling efficiency using nanopowders. These three enhancement mechanisms increase the number of the three participating carriers (electron, photon, and phonon) in the interacting volume.